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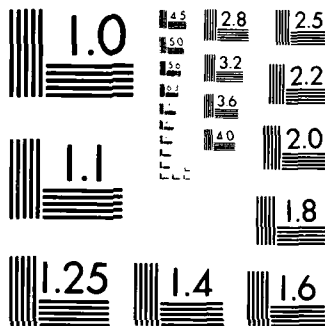
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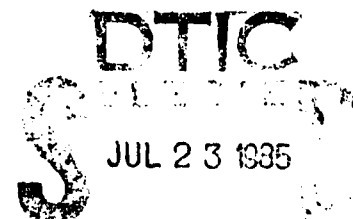
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SARSAT LUT TO CMCC ALERT DATA INTERFACE A CRITICAL REVIEW

by

W.R. McPherson and S.Y. Slinn

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TECHNICAL NOTE 84-24

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SARSAT LUT TO CMCC ALERT DATA INTERFACE A CRITICAL REVIEW

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W.R. McPherson and S.Y. Slinn
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Electronics Division

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ABSTRACT

The transfer of beacon alert data from the SARSAT Local User Terminal (LUT) to the Canadian Mission Control Centre (CMCC) has shortcomings. A critical review of the transfer of information between these two SARSAT facilities was undertaken. As a result of this review, a recommended LUT to CMCC data flow methodology has been developed, characterized and evaluated. Implementation of the recommendations outlined should improve the operational usefulness of the SARSAT system.

RÉSUMÉ

Le transfert, depuis la station terrestre à utilisation locale (LUT) au Centre canadien de contrôle des missions (CCCM), des données d'alerte émises par les balises présente des lacunes. On a fait un examen critique du transfert de données entre deux installations du SARSAT. À la suite de cet examen, une méthode applicable au flux de données entre LUT et CCCM a été mise au point, défini et évaluée. Grâce aux recommandations formulées, l'utilité opérationnelle du SARSAT devrait être accrue.

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1.0 INTRODUCTION

The transfer of beacon alert data from the SARSAT Local User Terminal (LUT) to the Canadian Mission Control Centre (CMCC) has shortcomings. On the one hand, the LUT provides alert data quality indicators which during the SARSAT Demonstration and Evaluation (D&E) have been demonstrated to be inadequate, while on the other hand, it retains data descriptors which are required by operational personnel.

The purpose of this report is to critically review data available at the LUT, determine its operational utility and outline a definition of transfer from the LUT to the CMCC. The potential impact of implementing this definition will be assessed with the aid of historical data.

The subject work is documented in terms of the background to the problem, an outline of approach and analytical tools developed, validation of the approach, summary comments and recommendations.

Keywords: data transfer, data base, data transfer, data base

2.0 BACKGROUND

As background to the presentation of the development work undertaken at DREO, the SARSAT concept and its available facilities are briefly discussed. This is followed by a brief description of the current data transfer definition between the LUT and CMCC. With this background established, the current operational problems associated with this data transfer are discussed.

2.1 SARSAT Facility Overview

The basic concept of the SARSAT satellite-aided search and rescue mission is illustrated in Figure 1. The signals radiated by an emergency beacon, either an Emergency Locator Transmitter (ELT) or an Emergency Position Indicating Radio Beacon (EPIRB), are detected by a polar-orbiting spacecraft equipped with suitable receivers. These signals are then relayed to a LUT where the signals are processed to determine the location of the ELT or EPIRB. The fact that an alert has been detected, along with the location of the ELT or EPIRB, is then relayed to an appropriate Rescue Coordination Centre (RCC) for initiation of the search and rescue activities.

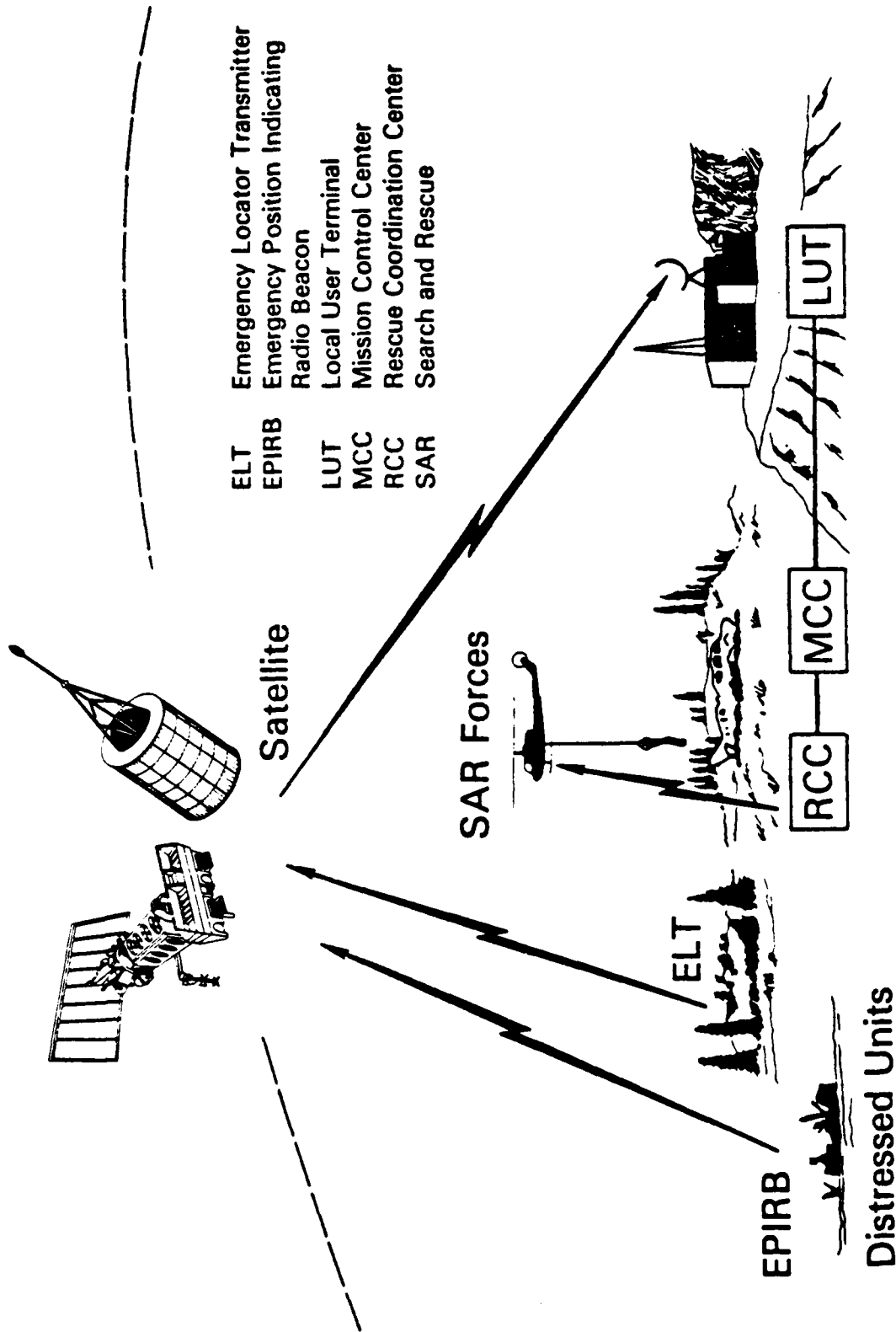


FIGURE 1: Basic Concept

Doppler-positioning techniques which use the relative motion between the spacecraft and the ELT/EPIRB were considered as a practical means of locating these very simple devices. All that is required is that the ELT/EPIRB emit a carrier frequency with a reasonable stability during the period of mutual ELT/EPIRB-satellite visibility. To optimize Doppler-positioning performance, satellites in a low-altitude polar orbit are used. The low altitude results in low ELT/EPIRB power requirements, good Doppler-shift characteristics and short time delays between successive passes. The use of polar orbits results in coverage of the whole earth.

Within the context of the current discussion, the SARSAT system consists of the following three subsystems:

- The first subsystem is the ELT and/or EPIRB. These small emergency transmitters are designed to transmit distress signals in the 121.5 and 243 MHz bands.
- The second subsystem is the spacecraft (SARSAT and/or COSPAS) which receives these signals and retransmits them at 1544.5 MHz to a ground station for processing.
- The third subsystem is the Local User Terminal (LUT), which is the ground station that receives the relayed distress signals. These signals are processed within the LUT to establish a beacon position location which is then transmitted to a Mission Control Centre (MCC).

The work being discussed herein is focused within the third subsystem. Specifically, the problem being addressed is associated with the definition of the transfer of distress data from a LUT to the Canadian MCC.

2.2 Current Data Transfer

The current data transferred by the LUT to the CMCC for each alert detected is as illustrated in Figure 2.

<u>Line #</u>	<u>Content</u>
1	121.5 ELT-EPIRB/160/01612 LUT 10 1511715Z 81
2	EN 02
3	SPCRFT ID S02/0 NB 01135/DATA SRC LUT 10 OTTA
4	PROC COMP 002 1750Z 80
5	LOC A/LAT 52 22.5 N/LONG 045 36.5 E
6	ERROR EST ANG 010/MAJ 12.3/MIN 04.5/PROB 55
7	LOC B/LAT 51 31.3 N/LONG 047 22.4 E
8	ERROR EST ANG 009/MAJ 12.6/MIN 04.7/PROB 45
9	QUALITY FACTOR 123456

FIGURE 2: Sample LUT-CMCC 121.5 ELT-EPIRB Transfer File

Data provided by the LUT consists of descriptor data, e.g. spacecraft identification, date, source, event times, etc., the location data (real and image locations), error estimates, and a quality factor.

SARSAT D&E results, using LUT data operationally, have indicated that quality parameters associated with the estimate of beacon location, i.e. lines 6, 8 and 9 in Figure 2, do not meet the users needs. The error ellipse does not adequately model the error (an empirical scale factor of three has been suggested to correct this inadequacy), the quality factor has only limited applicability, and the probability factor does not have sufficient sensitivity, except in unusual cases, to resolve ambiguity.

As a result of the above, the end user of the SARSAT data, the CMCC operator and ultimately the RCC controller, must take the estimations of beacon location at their "face value", and action all data provided by the system in the same way. Work at DREO suggests that through better visibility into LUT data, operational users of SARSAT data can determine their level of response and act accordingly.

2.3 Statement of the Problem

Therefore, the problem existing at the operational level is one of a lack of qualifiers being provided with SARSAT alert data. The user is forced to treat all SARSAT data in the same manner. The CMCC operators and RCC controllers cannot measure their response to the alert data and act accordingly. The end result of the above is that operational users are unable to fully benefit from the SARSAT system.

3.0 OUTLINE OF APPROACH AND ANALYTICAL DEVELOPMENT

The problems associated with the LUT data and the inadequate guidance being given by the SARSAT system to the users was realized soon after data began to flow in 1982. It has been discussed many times in numerous different forums over the past few years. However, little has been done to resolve the problem. The assumption generally made was that operational personnel would work around the problem.

The belief that the above was not a responsible approach on the part of the SARSAT system designers has led to the developmental work outlined in the following discussion. This work, initiated at DREO, is presented in terms of its objectives, a definition of LUT data quantifiers, and the LUT to CMCC data transfer flow. Specific attention is given to a LUT cluster analysis process and a CMCC pass-to-pass merge algorithm.

3.1 Objective

The objectives of the studies discussed herein are to demonstrate that:

- SARSAT users can be better served and hence can react more appropriately if they are given more information about the alert data being generated by the system;
- Simple but highly effective alert data descriptors are either available from the current LUT data base, or, can be generated quite easily;
- The CMCC requires a pass-to-pass merge algorithm to update incoming data from the LUT, and, such an algorithm is easy to develop.

3.2 Data Quantifiers

For each SARSAT alert at 121.5/243 MHz, the Canadian LUT generates a record in the WLSDAT file. This file contains the beacon location information and associated data which was obtained as a result of the estimation process. The current definition of this file is as given in Table 1.

Word	Description
1	satellite identifier
2	orbit revolution number
3	orbit determination and prediction
4-6	time of acquisition of signal (seconds from 1980)
7-9	time of loss of signal (seconds from 1980)
10-142	not used (zero)

Table 1(a): WLSDAT Record Formats (Header Record)

Word	Type	Description
1	I	If 406 MHz, ELT identifier (60 bits), if 121.5/243.0 MHz, 4 ASCII blanks and real correlation score.
5	I	Data type used to generate solution (see Table 1(c))
6-8	D	Time ELT position was calculated (seconds from 1980)
9-10	R	Initial estimate of cross-track angle (deg)
11-12	R	Initial estimate of time of closest approach (seconds from TAOS)
13-14	R	Initial estimate of frequency bias (Hz)
15-78	-	More probable solution (see Table 1(d))
79-142	-	Less probable solution (see Table 1(d))

Table 1(b): WLSDAT Record Formats (Data Record)

Bit Set	Data Type
0	DAT406: 406 MHz "Bent Pipe" data
1	DAT406: 2.4 Kb/s real time data
2	DAT406: 2.4 Kb/s COSPAS stored data
3	CBC121
4	CBC243
5	IAV121
6	IAV243
7	SST121
8	SST243

Table 1(c): WLSDAT Record Formats (Data Type (word 5)).

Word*	Type	Name	Description
15-16	R	ALAT	ELT latitude (deg N)
17-18	R	ALONG	ELT longitude (deg W)
19-20	R	ALT	ELT altitude (meters)
21-22	R	CTA	Cross-track angle (deg)
23-24	R	TCA	Time of closest approach (seconds from TAOS)
25-26	R	BIAS	ELT frequency bias (Hz)
27-28	R	DRIFT	ELT frequency drift (Hz/min)
29	I	NPTS	Number of frequency measurements
30	I	NITER	Number of WLS iterations
31-32	R	AMEAN	Average of data residuals (Hz)
33-34	R	SDEV	Standard deviation of data residuals (Hz)
35-36	R	TREND	Trend factor of data residuals (Hz)
37-44	R	VARY	Standard deviation of CTA, TCA, BIAS, DRIFT
45-56	R	CORR	Correlation coefficients
57-58	R	TIMSTA	Time to first frequency measurement (seconds from TAOS)
59-60	R	TIMEND	Time to last frequency measurement (seconds from TAOS)
61-62	R	PROB	Probability of true solution (and not ambiguous one)
63-64	R	VLAT	Standard deviation of latitude (deg)
65-66	R	VLONG	Standard deviation of longitude (deg)
67-68	R	CLALO	Correlation coefficient between latitude and longitude (normalized)
69-70	R	MAJOR	Major axis of error ellipse (km)
71-72	R	MINOR	Minor axis of error ellipse (km)
73-74	R	HEAD	Heading angle of error ellipse (deg)
75	I	EXPECT	Expected circular error (km)
76	I	SEACH	Expected search area (km ²)
77	I	QUAL	Quality factor for CBC data (sum amplitudes)
78	I	MESS	Flag indicating whether the ELT data was sent via an alert message (0=no, 1=yes)
* For less probable solution, add 64 to word number.			

Table 1(d): WLSDAT Record Formats (Solution Data).

Drawing from data available from the WLSDAT file, parameters associated with the location estimate are defined under the following headings:

- Quality
- Geometry
- Frequency
- Ambiguity
- Merge

In order to emphasize a range of uses of these data, output from the DREO development activity is categorized as being either primary or secondary data. Primary data has direct operational use while the secondary data is needed for internal CMCC operations and more detailed technical support. A sample output from a DREO LUT emulation process is illustrated in Figure 3. This process will be discussed in subsequent sections. Prior to that discussion, the definitions of the data quantifiers illustrated are given.

3.2.1 Quality Parameters

Primary quality parameters requiring definition include:

- CAT
- Q
- CL SIZE
- SIG TYPE

CAT - Quality Category

A number of different approaches have been suggested to categorize the quality of the alert data. On the basis of simplest is best, the current favoured approach is the following:

CAT	Definition
A	$0 \leq \text{STD} \leq 8$
B	$8 < \text{STD} \leq 18$
C	$18 < \text{STD} \leq 40$
D	$\text{STD} > 40$

The category of the signal is based solely on the standard deviation of data residuals (Hz), i.e. SDEV found in the WLSDAT file.

Q - Quality Factor

Q is intended to be a measure of the density of the Doppler curve taking into account geometry effects. It is a measure of the amount of data in the curve relative to an ideal curve. It therefore ranges in value from 0.0-1.0, one being equated as perfect in terms of data density (but not necessarily trend).

The ideal curve is defined to be one which consists of 450 points or spans a time of 15 minutes. Therefore

$$\begin{aligned} N_0 &= 450 \\ T_0 &= 15 \text{ minutes} \end{aligned}$$

DATA RETRIEVAL PROCESS

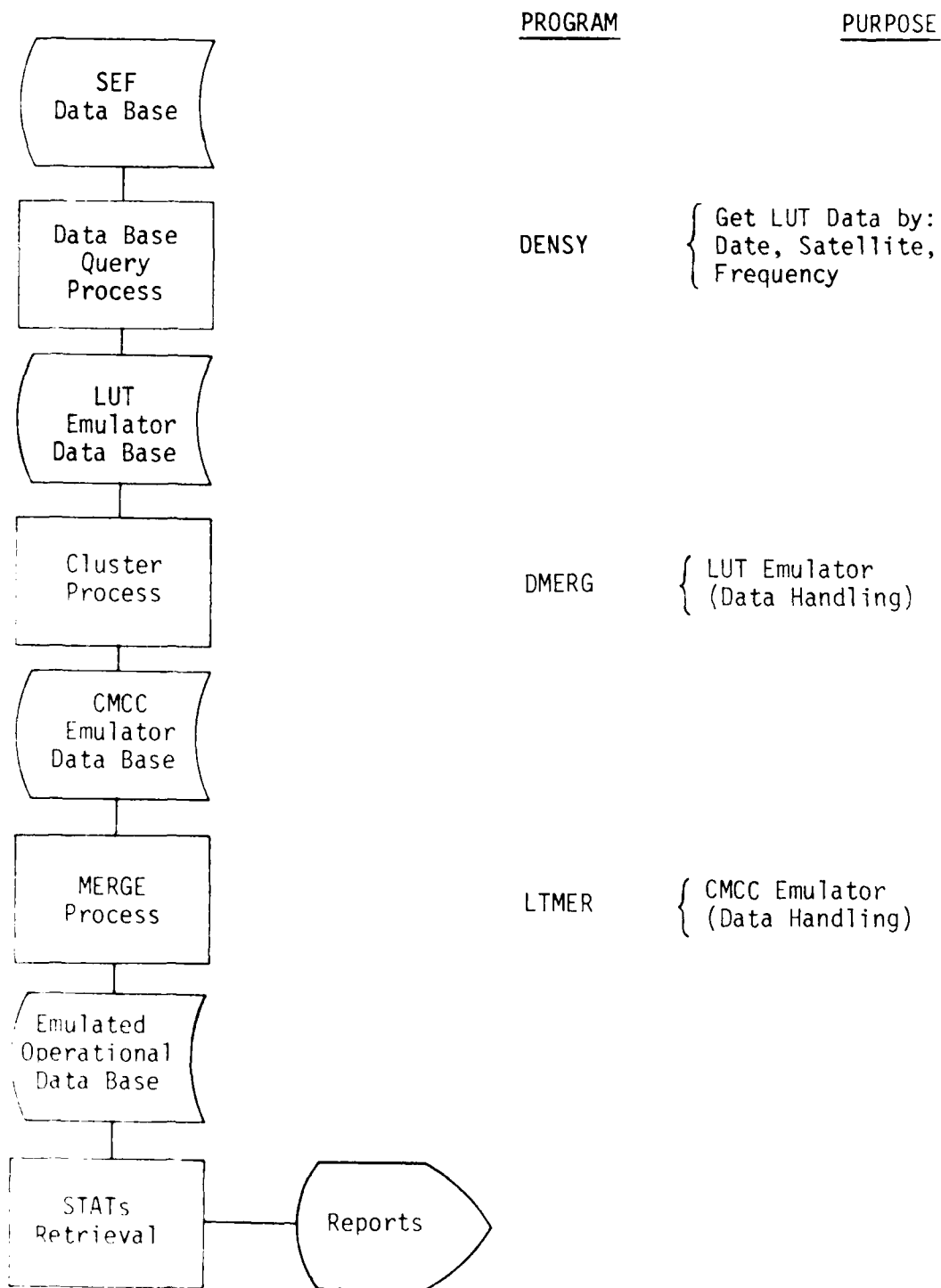


FIGURE 7: LUT/CMCC Emulation
Processing Flow

As background to the presentation of the results of the LUT to CMCC emulation, the method of approach is described. An overview of the results from the sample period is then presented. The impact of both the cluster and merge processes are discussed, and the utility of the previously described location data qualifiers are demonstrated. Finally, a number of case studies, related to the Kalman Filter process, which illustrate the effect of multiple detections are presented.

4.1 Method of Approach

As part of the SARSAT D&E activity, the SARSAT Project Office developed the SARSAT Evaluation Facility (SEF). In effect, this constituted a structured computerized data base of LUT, CMCC and SAR evaluation data. Data from the LUT and CMCC for the period 1 Jan 83 to 1 Oct 84 were routinely stored on magnetic tape, transferred to the SEF and incorporated into the data base. Operational search and rescue data are available in paper format and can be manually integrated with the SARSAT evaluation data. Therefore, online access is available for any sample period in the aforementioned time range.

In order to test the LUT to CMCC data flow as described in Section 3 and illustrated in Figure 4, the approach adopted was to build a LUT/CMCC emulator. The input to the emulator would be historical LUT data. The advantage of this approach is that in the first instance, it characterizes the SARSAT environment, particularly at the LUT, but also, it offers the opportunity to assess the impact of the output from the LUT to the CMCC when different filters are applied to the data.

Considerable software development was required to produce the LUT/CMCC emulation illustrated in Figure 4. The general approach was that as illustrated in Figure 7. It is not the intention to document herein the developed analytical tools used to support the study results, but rather to overview the approach. The developed software are documented elsewhere.

Therefore, referring to Figure 7, the general data retrieval flow was as follows. Using the SEF data base, previously described, a program called DENSY was developed to access LUT data. This program allows retrieval of data according to a number of criteria, for example, a date range, satellite used, beacon transmission frequency, etc. Essentially, the DENSY program accesses the WLSDAT files described in Table 1 and produces a set of data files which are used to "drive" the simulation. These data can be viewed as the WLSDAT data retrieved in accordance with the selected DENSY input criteria. The resulting data is referred to as the LUT Emulator data base.

At this stage of the process flow, the objective was to simulate the LUT handling the WLSDAT data in a manner illustrated in Figure 4. A cluster analysis was carried out on the data and the previously described data quality parameters calculated. A cluster representative was selected and output files produced to simulate transmission of data from the LUT to the CMCC. The result is the CMCC Emulator data base formed by the program

These are the parameter data for each location for the real and image solutions, but also, a linked list of case numbers derived as a result of the merge process. For example, Case 15 in Figure 6 has a MERGE NO of two. This means that two cases are associated with this location, i.e., Case 15 and although not explicitly illustrated, Case 3. The entries in Case 15, LUT real solution, are the output of the Kalman Filter, not the results from the LUT pass 2 processing. The image data in the Case 15 data entry are the LUT parameters which necessarily are not used in any future processing.

Lastly, the AMBG FLAG traces the current estimate identifying which solution is the true solution, zero implies the true solution and 1 implies the image solution. Since in many cases the LUT cannot distinguish between the real and ambiguous location, this flag is redefined when image data is successfully matched against previous cases. In this way, the LUT input data ordering is maintained while at the same time, case ambiguity resolution is identified.

The PASS, CASE, MERGE and DATA files as described are really internal files designed to allow user access to the data in accordance with his needs. A couple of such access examples are illustrated. The user may require the output of all active cases. The CASE file is interrogated, starting from the oldest active file, and the case status is read. The status flag is interpreted to distinguish between active single detections and merged cases (ambiguity resolved). The MERGE file data provides the current estimate of the transmission location while the DATA file provides the ancillary confidence data. Regional distribution of the data can be effected by checking the Region indicator (it is presumed that the CMCC carried out the region calculation upon receipt of the cluster data and entered the region indicator into the primary set before concatenating the cluster data to the DATA file). The user may want to manually review all single detections with good quality indicators. The rationale here is that merged events are able to be handed off for immediate SAR action while low quality single detections may not contain sufficient information for any actioning. Therefore it may be useful to review the good single detections and try and correlate these data against obvious signal location sources, i.e. populated areas, airports, etc.

As is evident, and as will be discussed in the next section, the files can support numerous statistical reporting processes which would help the CMCC personnel monitor their throughput.

4.0 ANALYTICAL TOOLS DEVELOPED/ VALIDATION OF APPROACH

The suggested approach as outlined has been studied in some detail. This was accomplished by selecting a sample period in time, retrieving historical LUT data for this period, mechanizing the approach previously discussed and analyzing the impact of the LUT to CMCC data flow.

CASE	PASS	LOCATION		MERGE FILE		VLONG	R	VRIAS	MERGE NO	AMRG FLAG
		LAT	LONG	RIAS	VLAT					
1	1	25.6891	-80.2051	6084	0060	0120	3806	1.1144	1	0
		26.8342	-60.1784	6060	0080	0140	4810	1.2300	1	1
2	1	43.1811	-61.0647	1258	0130	0240	6068	2.5249	1	0
		41.5586	-82.5943	1285	0110	0270	4650	2.8200	1	1
3	1	41.2932	-80.1616	7581	0030	0090	4752	6616	1	0
		42.6113	-63.5507	7542	0020	0090	0720	6400	1	1
4	1	29.0570	-81.0429	7949	0140	0180	1059	2.3479	1	0
		30.3538	-59.8293	7927	0170	0220	1330	2.7100	1	1
5	1	39.4377	-48.5624	12137	0640	0510	0572	5.8715	1	0
		36.4135	-92.5065	12154	0570	0450	0460	5.7400	1	1
6	1	44.1270	-99.0733	13112	0700	0900	5498	8.6023	1	0
		48.3971	-42.9190	13091	1070	1170	5350	10.6400	1	1
7	1	40.3402	-84.8193	7587	0370	0410	1463	4.5068	1	0
		42.4001	-58.1002	7580	0470	0500	0440	5.4400	1	1
8	1	47.7081	-55.6360	10661	0390	1310	2840	5.9535	1	0
		44.9938	-88.6591	10721	0480	1220	5640	6.8100	1	1
9	1	31.0544	-79.2161	7745	0490	1230	2072	8.2775	1	0
		32.2397	-62.0176	7743	0580	1400	4450	8.2600	1	1
10	1	38.9284	-96.3480	12930	1870	1330	1675	2.0140	1	0
		42.5228	-44.6787	12904	2240	1680	2960	23.7800	1	1
11	1	39.0065	-76.8162	21951	0120	0280	0195	1.8102	1	0
		39.7953	-66.1869	21943	0140	0290	2120	1.8300	1	1
12	1	32.2933	-86.4555	24009	0620	0570	5819	8.9683	1	0
		34.4922	-54.6235	24008	0660	0720	6160	9.6600	1	1
13	2	41.6978	-103.1169	13100	0030	0130	6290	6195	1	0
		42.4738	-93.4919	13079	0030	0140	0690	5900	1	1
14	2	33.1197	-97.3520	11922	0160	2490	9786	7065	1	0
		33.0119	-98.2518	11939	0040	0480	6660	5400	1	1
15	2	41.2922	-80.1747	7551	0025	0055	3349	3127	2	0
		38.8778	-114.6493	7666	0080	0120	1220	1.0300	1	1

FIGURE 6: Sample Merge File

will support retrieval of case data based on time, satellite type, source and/or satellite orbit number.

The CASE file consists of one entry for each cluster derived by the detecting LUT. Its primary purpose is to control the merging and aging process of the CMCC data. For this purpose, case time, status and case type are logged into the file. Time is carried in the rather arbitrary form of number of days since 1950. The exact basis of the time scale is not important since it is only used to measure the relative passage of time. The case and pass numbers provide pointers to the DATA and PASS files. The status flag is important to the merge process. It identifies the case status through the assignment of the following indicators:

Status Assignment	Meaning
-1	Single Detection, Case Aged Out
0	Single Detection, Case Active
1	Merged Case, Data Superceded
2	Merged Case, Case Active
3	Merged Case, Case Aged Out

The type flag indicates the number of merges that have occurred on the case data up to and including the time of processing of the case.

The CASE file is intentionally defined to be small in terms of record length since it is continually accessed during the merge process. When data are received at the CMCC, it is suggested that the CASE file be interrogated to find the oldest active case, i.e. the status flag is used for this purpose. At the same time, the case time is compared to the incoming pass time and if it exceeds the "aging" criteria, the case is aged out of the system by a suitable redefinition of the status flag. At this stage all active cases (those with Status = 0 or 2) are compared to the incoming pass data, and if a comparison is successful, the case status reverts to, Merged Case, Data Superceded (Status flag = 1) and a MERGE file entry is recorded. If a case from the current pass does not merge with previous pass data, then it is entered into the MERGE file as a single detection, case active (Status flag = 0 in the CASE file).

Figure 6 illustrates output from a MERGE file. It contains the case and pass numbers for access back to the CASE and PASS files and as required, direct access to the source data in the DATA file. The location and frequency bias data are also logged into this file. If the case is a single detection (either active or aged) then the location and bias estimates are the data as provided by the LUT. If, however, a comparison was successful, i.e. a merge took place, then the location and bias data in the MERGE file are the output results of the Kalman Filter calculation described in Section 3.3.5. Therefore, the entry in the MERGE file for a particular case is the system's best estimate of the location and associated parameters of the transmission. The source data for the particular pass is retained in the DATA file. The VLAT, VLONG, R and VBIAS parameters are the input to the Kalman Filter.

The MERGE NO is the size of the merge list (not illustrated in Figure 6). The MERGE file has four records associated with each case.

PASS FILE

PASS	TIME	DATE	SATPAS	AOS	LOS	LUT	NO CLUSTERS	NO DETECTS	CASE START	END
1	12662 10	840901	C2 07222	2.52	2.82	10	12	17	1	12
2	12662 18	840901	C2 07223	4.29	4.55	10	11	24	13	23
3	12662 23	840901	C3 00981	5.72	6.01	10	7	14	24	30
4	12662 31	840901	C3 00982	7.49	7.73	10	8	19	31	38
5	12662 38	840901	C1 10860	9.14	9.42	10	6	11	39	44
6	12662 45	840901	C1 10861	10.90	11.19	10	6	10	45	50
7	12662 53	840901	C1 10862	12.76	12.94	10	3	3	51	53
8	12662 59	840901	C2 07229	14.35	14.61	10	5	5	54	58
9	12662 67	840901	C2 07230	16.08	16.38	10	6	8	59	64
10	12662 74	840901	C2 07231	17.91	18.13	10	2	2	65	66
11	12662 76	840901	C1 10865	18.35	18.52	10	3	5	67	69
12	12662 80	840901	C3 00989	19.29	19.58	10	7	10	70	76
13	12662 83	840901	C1 10866	20.09	20.38	10	7	9	77	83
14	12662 88	840901	C3 00990	21.13	21.32	10	3	3	84	86
15	12662 91	840901	C1 10867	21.86	22.15	10	9	9	87	95

CASE FILE

CASE	PASS	TIME	STATUS	TYPE
1	1	12662 10	1	1
2	1	12662 10	1	1
3	1	12662 10	1	1
4	1	12662 10	1	1
5	1	12662 10	1	1
6	1	12662 10	1	1
7	1	12662 10	1	1
8	1	12662 10	1	1
9	1	12662 10	-1	0
10	1	12662 10	-1	0
11	1	12662 10	1	1
12	1	12662 10	1	1
13	2	12662 18	-1	0
14	2	12662 18	1	1
15	2	12662 18	1	2
16	2	12662 18	1	1
17	2	12662 18	3	1
18	2	12662 18	1	2
19	2	12662 18	3	1
20	2	12662 18	1	2
21	2	12662 18	-1	0
22	2	12662 18	1	1
23	2	12662 18	1	2
24	3	12662 23	1	2
25	3	12662 23	3	1
26	3	12662 23	3	1
27	3	12662 23	1	2
28	3	12662 23	3	1
29	3	12662 23	3	1
30	3	12662 23	1	2
31	4	12662 31	3	1
32	4	12662 31	1	2
33	4	12662 31	1	2
34	4	12662 31	1	1
35	4	12662 31	1	1
36	4	12662 31	-1	0
37	4	12662 31	-1	0
38	4	12662 31	1	2
39	5	12662 38	1	2
40	5	12662 38	1	2

FIGURE 5: Sample PASS and CASE Files

distance criteria is to identify clusters or groupings of locations which tend to indicate the detection of an ELT/EPIRB and its associated sidebands. In the absence of a specific ELT/EPIRB identifier, the estimated bias of the beacon is used to distinguish two different transmissions in the same region.

The algorithm to develop the clusters is quite straightforward in its mechanization. In its simplest terms it is a triangulated compare process with a 'knock out' activity when the comparison is successful. The general flow is as follows. The pair of locations for the first detection are compared to all the other detections, and when comparisons are positive, the latter events are removed from the system. The cluster process then continues until all groupings are identified. The end result is a re-ordered WLSDAT file for the particular pass.

During the cluster analysis, the parameters Q, PROBT, ELEV, and ABS are calculated as discussed in Section 3.2. The CL SIZE and FREQ FLAG are established as part of the process. Finally, the SIG TYPE, CTA and TCA flags are set in accordance with the criteria previously discussed. The output from the cluster analysis is the CLUSTER file, as noted in Figure 4.

The final step in the cluster analysis is the selection of a representative element from each cluster. The criteria which was used, for this selection was to pick the first element in the cluster. The LUT, in its Doppler processing, extracts the Doppler curves in order of signal strength. Therefore, the first element in the cluster is the best estimate because it was the strongest signal. Other selection criteria or approaches are possible.

Figure 3 illustrates a sample pass resulting from the cluster analysis. The parameters given in Figure 3 are those suggested to be transferred from the LUT to the CMCC.

3.5 CMCC MERGE Process

The CMCC, upon receipt of the data from the LUT (or conceivably any other source that can support the parameter definition), appends pertinent data to a PASS file, CASE file and the main DATA file. Sample structures for the PASS and CASE files are illustrated in Figure 5. The DATA file is simply a concatenation of CLUSTER files.

The PASS file has the dual function of being a pointer file and a historical statistical reference file. Upon receipt of the cluster data, the PASS file is updated with the basic pertinent data related to the pass. A CMCC pass number is assigned, the pass time, satellite used and source of the data are recorded. Basic LUT statistics are also noted, i.e. the number of LUT detections and the number of derived clusters. The latter is a measure of data compression as a result of the cluster analysis. Each cluster is now considered as a CMCC case, analogous to the currently defined CMCC reference number. The range of case numbers assigned as a result of the pass are logged in the PASS file. Therefore, the PASS file

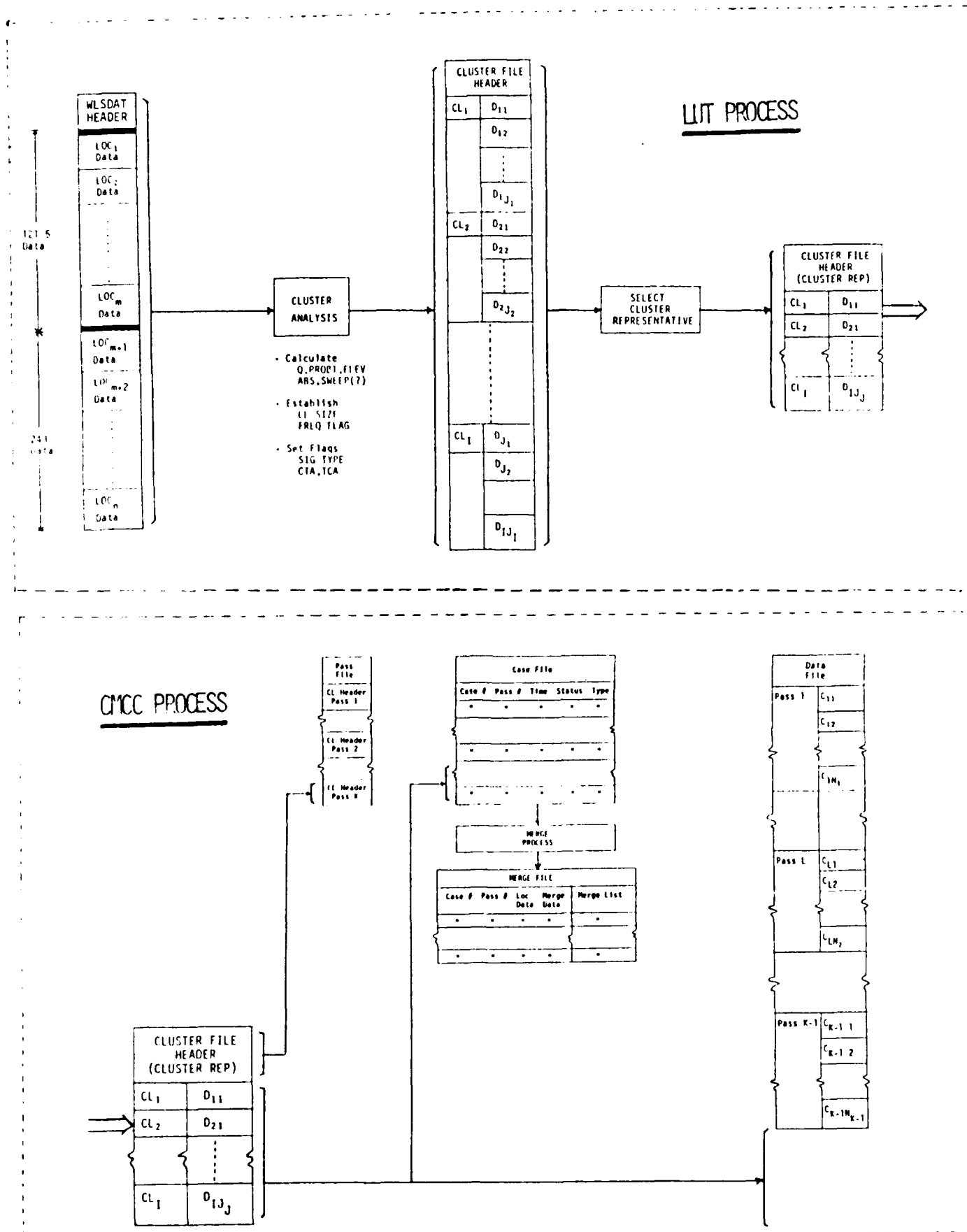


FIGURE 4: LUT/CMCC Data Flow/Process

- The LUT, a signal processor, has only a minimal role as a collator of information;
- The LUT process is a real time activity, it carries no history with it;
- The CMCC has visibility into the total SARSAT environment both nationally and internationally;
- The CMCC carries history and the age when alert data from the LUT is considered inactive is under the control of the CMCC operator.

Figure 4 summarizes the suggested LUT to CMCC data flow process. The process begins with the production of the WLSDAT file, see Table 1, one record is created for each ELT/EPIRB detected by the LUT. The WLSDAT data is subjected to a cluster analysis in which data is grouped and ordered according to a distance and beacon bias check criteria. This process is discussed in more detail in the next section. The result of this process is the cluster file. A representative from each of the developed clusters is then selected for transmission to the CMCC.

The CMCC, upon receipt of the cluster data from the LUT, initiates a number of actions. Firstly, a PASS file containing pertinent historical information related to satellite passes processed is updated. This file contains such information as a pass number (similar to the CMCC reference numbers or case number), time of pass, date, SATPAS and AOS/LOS, number of clusters in the pass, etc. A CASE file is also updated to contain a case number (currently called the CMCC reference number), the above mentioned pass number, and status of the case. The MERGE file besides containing the case and pass numbers, has the beacon location data, merge update data and most importantly, the merge list. The merge list is a backward looking linked list identifying all previous detections associated with the current active case. The creation of the MERGE file through a merge process is discussed in Section 3.5. Finally, the master data file, containing all the cluster data incoming from the LUT is updated.

Through simple linkage between the MERGE, CASE, PASS and DATA files, the pertinent summarization of the data can be presented to the CMCC operator for his review and onward transmission to the RCC controllers for their action.

The next two sections consider in more detail the cluster analysis, suggested to be carried out at the LUT, and the merge process, intended to be performed at the CMCC.

3.4 The LUT Cluster Process

As illustrated in Figure 4, the LUT cluster process involves a total review of the WLSDAT file for a given pass (121.5 MHz data, and 243 MHz data if available), and grouping these LUT generated detections based upon a distance and the beacon frequency bias. The intention of the

where ϕ_n = latitude V_{ϕ_n} = Variance in the latitude estimate.
 λ_n = longitude V_{λ_n} = Variance in the longitude estimate.
 ρ = correlation between latitude and longitude in the estimation.

A number measurement is made resulting in an updated vector X and associated covariance matrix C .

In order to update the state vector X_n , the Kalman gain vector is calculated by:

$$K = C_n (C_n + C)^{-1}$$

and

$$X_{n+1} = X_n + K(X - X_n) \text{ and } C_{n+1} = (I - K)C_n$$

In an analogous manner, BIAS can be updated using the variance on the BIAS as provided in the WLSDAT file

i.e.

$$B_{n+1} = B_n + \frac{V_{B_n}}{V_B + V_{B_n}} (B_n - B)$$

and

$$V_{B_{n+1}} = \frac{V_B V_{B_n}}{V_B + V_{B_n}}$$

3.3 LUT to CMCC Data Transfer Flow

Given the LUT to CMCC parameter definition as described in Section 3.2, it is now useful to consider the flow of information in a more global sense. The following discussion is premised on the assumption that the LUT and CMCC functional activities should take into account the following:

3.2.3 Frequency Resolution Parameters

A FREQ Flag is included in the primary data set to note whether as a result of the clustering process, the observed cluster frequency is 121.5 MHz (Flag=8), 243 MHz (Flag=16) or Dual frequency 121.5/243 MHz (Flag=24).

Due to operational requirements, the estimated absolute frequency of the beacon is provided in the secondary data, i.e.

$$ABS = 121.5 + \left(\frac{BIAS}{1000} - 12.5 \right) \div 1000$$

The estimate of BIAS, as taken from the WLSDAT file is given, and a space is provided for the estimated SWEEP rate. The latter is provided as a reserve field should future LUT developers elect to have this parameter incorporated into new LUTs.

3.2.4 Ambiguity Resolution Parameters

PROBS is the probability of ambiguity resolution using the standard deviation, and is available from the WLSDAT file. PROBT is the probability of ambiguity resolution using TREND. The method of calculation is identical to that of PROBS except TREND is substituted for SDEV.

3.2.5 Merge Parameters

It is not logical to perform intra pass merging at a LUT especially in a multi LUT environment. It is logical to merge data between passes at the CMCC. In order to do this, the following parameters are included in the secondary data to support merge operations:

VLAT = standard deviation of the latitude estimate;
 VLONG = standard deviation of the longitude estimate;
 CLALO = correlation between latitude and longitude;
 VBIAS = standard deviation of the BIAS.

The algorithm to update the location estimate is that provided in the LUT, see SM-LUT-284/1, page 3-2. It is a simple Kalman Filter technique and is summarized as follows.

At a given period in time there exists a state vector X_n of latitude and longitude and an associated covariance matrix C_n which define the state just prior to the arrival of new information. X_n and C_n are of the form

$$X_n = \begin{bmatrix} \phi_n \\ \lambda_n \end{bmatrix} \quad C_n = \begin{bmatrix} V_{\phi_n} & \rho \sqrt{V_{\phi_n} V_{\lambda_n}} \\ \rho \sqrt{V_{\phi_n} V_{\lambda_n}} & V_{\lambda_n} \end{bmatrix}$$

CL SIZE

CL SIZE is the numerical cluster size derived at the LUT by merging sidebands according to distance and bias criteria. In the case of dual frequency transmission, CL SIZE would reflect the merging by frequency as well.

SIG TYPE

SIG TYPE is a flag to annotate the type of signal observed. Its definition is based on the premise that a cluster of size one is suspect, a cluster in the range 2-5 is probably a good ELT/EPIRB signal with noted sidebands while a cluster that is greater than 5 tends to imply an interfering signal source.

Therefore SIG TYPE is defined as follows:

U	CL SIZE = 1
E	$1 < \text{CL SIZE} \leq 5$
I	CL SIZE > 5

The secondary data set related to Quality is: STD, TREND, PTS, NMWLS. The first three parameters are standard deviation, trend and no. of data points, given in their quantitative terms as available from the WLSDAT file, i.e. SDEV, TREND, NPTS. The NMWLS is the number of least squares iterations carried out (NITER in the WLSDAT file) and is a qualitative indication of the degree of difficulty encountered in deriving a solution. A value of NMWLS = -5 signals nonconvergence of the curve fitting process.

3.2.2 Geometry Parameters

At the primary level two flags, one related to the estimated cross track angle, CTA, and the other, time of closest approach, TCA, are provided. The flags are defined as follows:

<u>Flag</u>	<u>Value</u>	<u>Definition</u>
CTA	-1	$0 \leq \text{CTA} < 2$
	0	$2 \leq \text{CTA} \leq 18$
	1	CTA > 18
TCA	0	unless
	1	$\text{TCA} < (\text{AOS} - \text{TCACUT})$ or $\text{TCA} > (\text{LOS} + \text{TCACUT})$

where TCACUT is currently defined to be one minute.

The secondary level geometry parameters include the actual values for CTA and TCA plus an estimate of the ELT elevation angle.

and

$$Q = \left(\frac{N}{N_0} \right) CF$$

where

N = no. of data points, NPTS in the WLSDAT file, and CF is defined as follows:

$$\text{If } TCA + \frac{T_0}{2} < LOS$$

$$\text{and } TCA - \frac{T_0}{2} > AOS$$

$$\text{then } CF = 1$$

$$\text{If } TCA + \frac{T_0}{2} < LOS$$

$$\text{and } TCA - \frac{T_0}{2} < AOS$$

$$\text{then } CF = \frac{T_0}{\frac{T_0}{2} + [TCA - AOS]}$$

$$\text{If } TCA + \frac{T_0}{2} > LOS$$

$$\text{and } TCA - \frac{T_0}{2} > AOS$$

$$\text{then } CF = \frac{T_0}{\frac{T_0}{2} + [LOS - TCA]}$$

$$\text{If } TCA + \frac{T_0}{2} > LOS$$

$$\text{and } TCA - \frac{T_0}{2} < AOS$$

$$\text{then } CF = \frac{T_0}{LOS - AOS}$$

TCA, LOS and AOS are the standard definitions and are available in the WLSDAT file.

PRIMARY DATA SET

CL #	LAT	LONG	REGION	CAT	QUALITY	Q	CL SIZE	SIG TYPE	GEOMETRY	CTA	ICA	FREQ FLAG	AMBIGUITY	PROBS	PROBT	DET #	SEQ #	EVENT #	MESS SENT
1	41.2851	-80.2293	A		7888	4	E	0	0	0	8	68	92	1	1	1	1	1	1
2	38.9903	-48.1346	B		7808	2	E	0	0	0	8	32	8	5	5	2	2	1	1
3	25.7211	-80.1536	A		4329	1	E	0	0	0	8	52	66	7	7	3	3	1	1
4	24.1340	-50.4263	A		4329	1	U	0	0	0	8	48	34	8	8	4	4	1	1
5	41.3938	-82.7297	A		2380	1	U	0	0	0	8	50	49	9	9	9	9	0	0
6	38.4888	-45.6468	A		2380	1	U	0	0	0	8	54	70	8	8	4	4	1	1
7	39.8419	-76.8937	A		2802	1	U	0	0	0	8	46	30	9	9	9	9	0	0
8	37.2776	-51.4328	B		2802	2	E	1	0	0	8	51	51	11	11	11	11	1	1
9	34.5678	-41.2634	D		1543	1	U	0	0	0	8	49	49	11	11	11	11	1	1
10	37.7478	-88.7290	D		1564	1	U	0	0	0	8	51	51	11	11	11	11	1	1
11	44.3607	-95.7467	C		2580	1	U	0	0	0	8	49	49	11	11	11	11	1	1
12	39.8146	-34.2580	C		2600	1	U	0	0	0	8	49	49	11	11	11	11	1	1

SECONDARY DATA SET

STD	TREND	QUALITY	PTS	MMWLS	CTA	GEOMETRY	ICA	ELEV	ARS	FREQUENCY	BIAS	SNEEP	VLAT	MERGE	VLONG	CLALO	VBIAS	DET #	SEQ #	EVENT #	CONTROL FLAGS
4.4818	0.7265	393	1	12.7833	9.2599	7888	121.4951	7652	0040	0060	0198	4729	1	1	1	1	1	1	1	1	1
9.5762	8.5842	389	1	-11.7880	9.2599	7808	121.4951	7632	0090	0120	-0220	9900	5	5	2	2	1	1	1	1	1
4.8822	0.9261	149	2	13.7601	9.1829	4329	121.4951	5834	0180	0170	5923	2.7270	5	5	2	2	1	1	1	1	1
5.3176	1.8325	149	2	-13.2194	9.1829	4329	121.4951	5796	0170	0180	5930	2.9400	7	7	3	3	1	1	1	1	1
6.7532	3.0089	119	3	14.6453	9.2614	2380	121.4951	780	0370	0520	8086	5.3869	8	8	4	4	1	1	1	1	1
6.8191	2.8684	119	3	-13.7953	9.2614	2380	121.4951	793	0390	0390	-7950	5.2800	8	8	4	4	1	1	1	1	1
7.8730	1.5662	133	3	10.3798	9.2481	2802	121.4951	21944	0130	0250	3379	1.8774	9	9	9	9	0	0	0	0	0
9.0772	3.6601	133	2	-9.7024	9.2481	2802	121.4951	21919	0130	0270	1800	2.1400	9	9	9	9	0	0	0	0	0
42.9002	34.0957	73	3	-18.3781	9.2473	1543	121.4951	12418	2690	2090	5614	3.1215	9	9	9	9	0	0	0	0	0
44.8578	36.1268	74	5	19.7583	9.2473	1564	121.4951	12434	3360	2230	-4600	35.3000	11	11	11	11	1	1	1	1	1
22.3297	19.7505	129	5	23.4179	9.2857	2580	121.4951	11379	2470	3020	8191	2.9387	11	11	11	11	1	1	1	1	1
23.0869	20.4158	130	5	-21.5021	9.2857	2600	121.4951	11384	2340	2190	-8050	22.3400	11	11	11	11	1	1	1	1	1

FIGURE 3: Sample Pass - Suggested LUT to CMCC Transfer File

DMERG. It should be noted that control is based upon satellite pass. This reflects the assumption that the LUT, as a facility, carried no history with it.

The CMCC Emulator data base can be viewed as a concatenated set of LUT data for which no pass-to-pass associations have been established. Using the program LTMER, these associations are developed. Starting at the beginning of the data files, LUT detections are compared on a pass-to-pass basis to establish multiple detections, the data is merged where appropriate and new location estimates are calculated. The merging process imposes a time window on the data and therefore allows detections to be aged out of the system, superceded by new detections, or remain active as the time window reaches the boundary of the test period.

The output from the merge process is data which is in a form available for operational actioning. It also provides the statistical basis upon which one can assess the impact of the whole cluster/merge process. These data are accessed by a program called MDUMP, the output from which is discussed in the following sections.

As a final footnote to this discussion on the method of approach, it should be noted that the data retrieval process illustrated in Figure 7 is a sequential process and not a real time handling of data as would be the case in the "real world". For the purposes of the studies in question, it would have been too time consuming to produce a real time simulation.

4.2 Test Period Selection

In order to run the LUT/CMCC emulation, a test period from which to retrieve historical data had to be selected. In a purely arbitrary fashion, the month of September 1984 was chosen. These data just happened to be conveniently available. Attempts were made to generate a data base for the full month but system difficulties were encountered because of file size problems. Rather than take the time to solve the computer system problems, the data base generated consisted of the first ten days of September, 1984, instead of the whole month. In reality, it is irrelevant which time period is chosen and how long the sample period is, as long as sufficient data are processed to produce stable statistics. In retrospect, the ten day period selected meet these requirements.

The results of the LUT/CMCC data flow emulation are summarized for the ten day period in question and then the impact of the cluster and merge processes are characterized.

4.3 Test Period Results - Overview

During the period 1-10 September 1984, the SARSAT facilities had access to the three operational COSPAS satellites. The summary of the cluster/merge process and the control parameters input to the emulation are given in Table 2 below.

TABLE 2
Cluster Merge Summary

Start Date: 840901
End Date: 840910

Summary

No. Passes Processed:	139
No. LUT Detections:	1222
No. Clusters Identified:	851

Input Parameters

Case Decay Time (hrs):	24.00
Distance Criteria (km):	250.00
Bias Range (Hz):	3000.00

During the sample period, the Ottawa LUT tracked 139 satellite passes or about 14 passes a day and produced 1222 ELT/EPIRB detections. While there is considerable diurnal variation, this equates to approximately 9 detections per pass. Out of these 1222 LUT detections, the previously described cluster process identified 851 clusters. The input criteria for the cluster process were as given in Table 2. For the merge process, a case decay time of 24 hours was selected. In other words, if a particular detected location was inactive for more than 24 hours, i.e. subsequent passes did not verify transmission, that location was aged out of the merge process.

Figure 8 summarizes the results of the cluster merge process for the 10 day period and the pertinent data are given in Table 3. Clearly, a number of generalizations can be made from these data.

Without totally justifying the comment at this time, the conclusion is drawn that the LUT generated data is very good. However, the end user, because of his lack of visibility into the details of these data, cannot distinguish better quality data from poorer quality data. The user is inundated with volumes of data which must all be treated in a like manner. Therefore, where possible, the volume must be reduced and then, the remaining data must be categorized.

In Figure 8, it is evident that 30% of the LUT generated beacon detection data can be suppressed at the LUT through the cluster process. These are the sideband data which in themselves are of no use to the user. Of the remaining 70%, 51% are classified as "U" Type transmission, i.e. single element clusters, 18%, in the absence of additional external information can be classified as ELT/EPIRB transmissions, i.e. clusters of size 2-5, and 1% are defined to be interferers. Therefore, based on cluster size alone and not taking into account the data quality indicators

TABLE 3

Cluster Merge Summary
Sample Period: 1-10 Sept 84

	No. Detections	Per Cent LUT Detections	Per Cent No. Clusters
"U" Type Transmissions			
No. Aged/Active	150	12.3	17.6
No. Merged	473	38.7	55.6
No. Superceded	350		
No. Aged/Active	123		
Total	<u>623</u>	<u>51.0</u>	<u>73.2</u>
"E" Type Transmissions			
No. Aged/Active	23	1.9	2.7
No. Merged	197	16.1	23.1
No. Superceded	149		
No. Aged/Active	48		
Total	<u>220</u>	<u>18.0</u>	<u>25.8</u>
"I" Type Transmissions			
No. Aged/Active	1	0.1	0.2
No. Merged	7	0.5	0.8
No. Superceded	5		
No. Aged/Active	2		
Total	<u>8</u>	<u>0.6</u>	<u>1.0</u>
No. Clusters	851	69.6	
No. LUT Detections	1222		

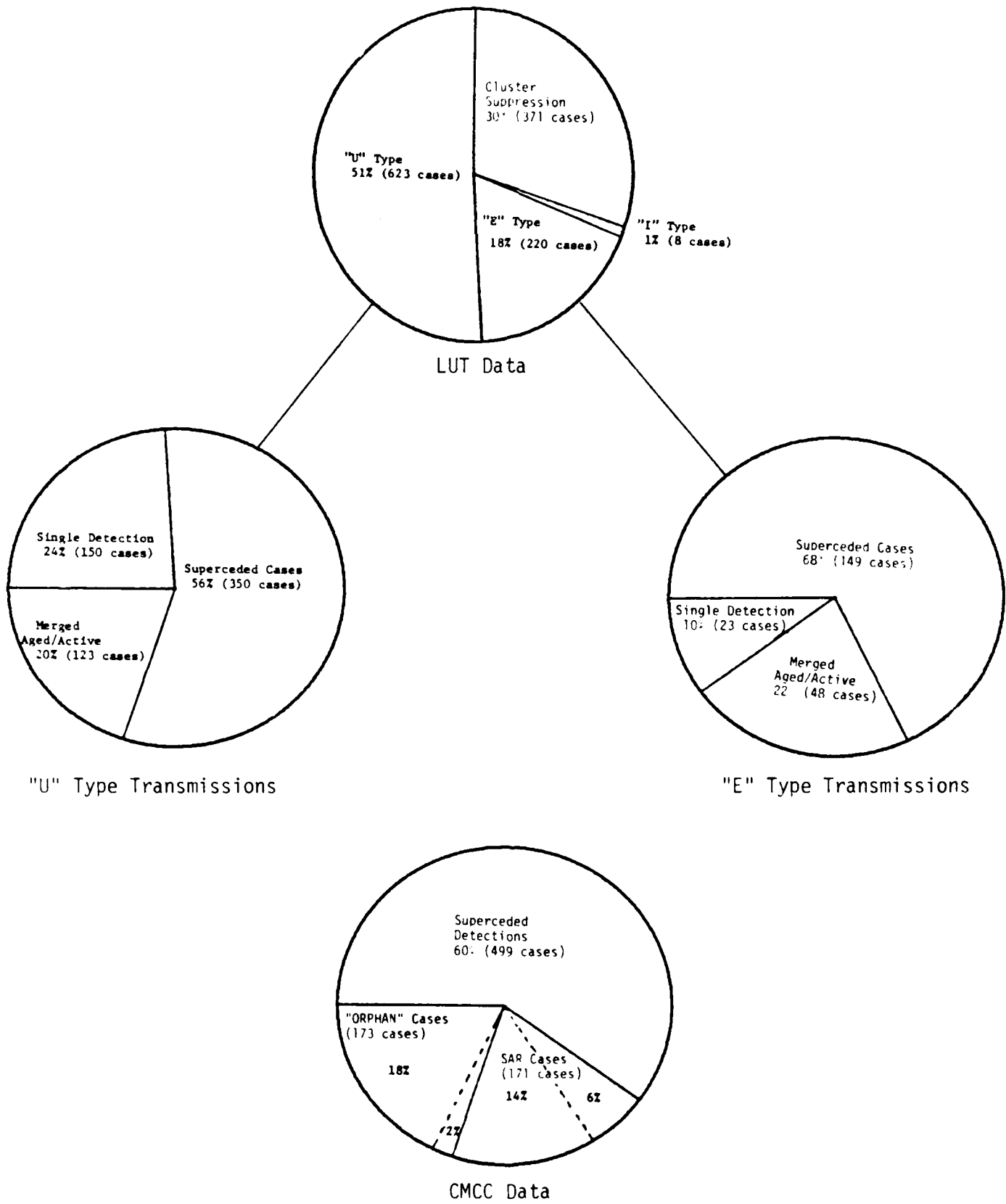


FIGURE 8: Cluster/Merge Summary

(these are discussed in subsequent sections), it is evident that 19% of the data generated by the LUT are amenable to immediate user action, 51% are amenable to qualified actioning and 30% require no action.

The "U" Type transmissions, which accounted for 51% of the LUT generated data, constitute the grey area. Figure 8 illustrates the fact that in 25% of these cases, no action is required. These transmissions were never verified, they were "orphan" events. On the other hand, only 10% of the "E" Type transmissions turned out to be "orphan" events. Therefore there is a limited risk, in terms of resource utilization, to action "E" Type transmissions immediately, while there is considerably more risk (and correspondingly there are more than twice as many cases) actioning "U" Type transmissions.

The summary cluster/merge data provided in Table 3 and Figure 8 allows one to convert the number of SARSAT detections into the number of search and rescue incidents. The definition for a SAR incident would be a verified SARSAT detection. Therefore of the 851 clusters suggested to be transferred from the LUT to the CMCC, 80% were validated to constitute 171 incidents. The conversion factor to translate SARSAT incidents into SAR cases is one in five. The SARSAT "False Alarm" rate is of the order of 20% i.e., 2 in 5 SARSAT detections are "orphan" events not verified by SARSAT, and 90% of these "orphan" events come from single element clusters.

The justification for the initial comment that the LUT generated data is very good is now clearly evident. 80% of the LUT data can be validated and it only remains to characterize the remaining 20% to assess its utility to the user.

4.4 Cluster/Merge Distribution

In order to lay the ground work for the role of the data quality indicators, to be discussed in the next section, the cluster size distributions derived for the sample period and the resulting merge distributions developed as a result of the merge process are illustrated.

4.4.1 Cluster Distributions

Figure 9 illustrates the cluster data developed through the cluster process in terms of size of the cluster. The data for the 851 clusters are then categorized in terms of whether a subsequent merge took place.

These data amplify the comments made previously, i.e. the size of the cluster can be used as a good indicator to determine the users initial reaction to incoming data. Data classified as "E" Type transmissions are actionable data. However, it is also evident that "U" Type transmissions cannot be ignored. As is illustrated, 56% of the single element data will

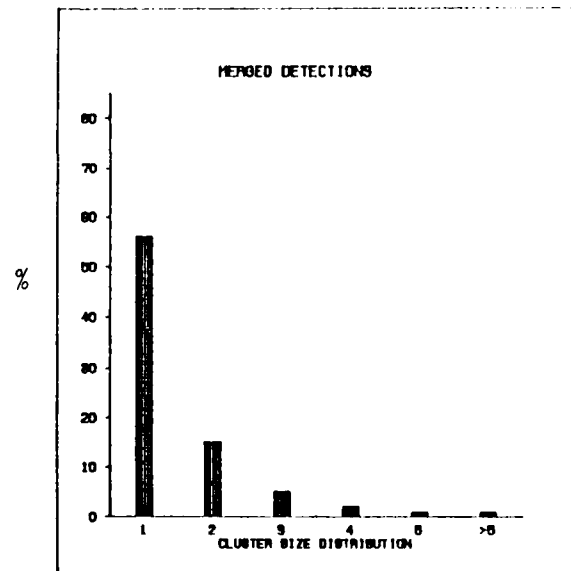
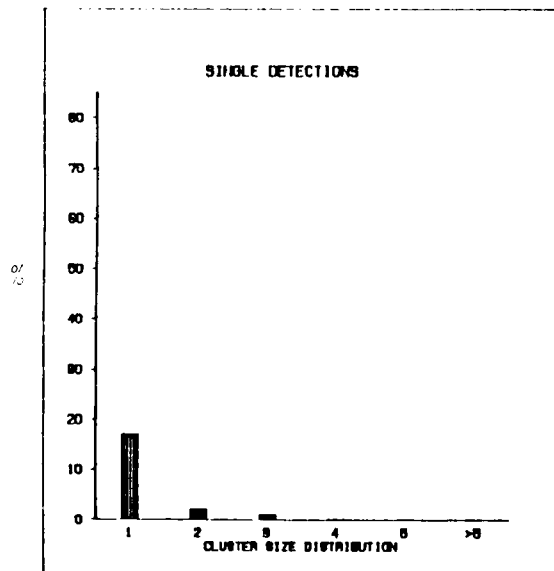
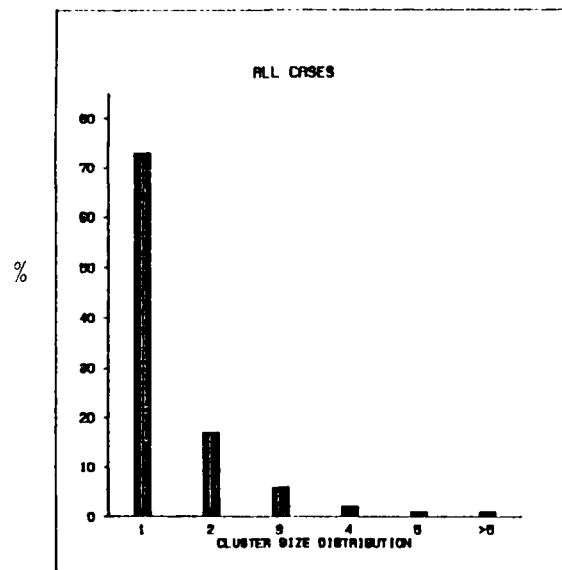


FIGURE 9: Cluster Size Distributions

subsequently be validated. It is these data that require further characterization in order to assess whether, through the use of additional information, rules can be developed to guide user actioning.

In summary, "E" Type transmissions, categorized solely on the basis of cluster size, can be viewed as ELT/EPIRB transmissions and hence are amenable to immediate user actioning. While "I" Type transmissions are not discussed in any detail, the implication or assumption made is that due to the nature of the transmission, they are actionable. Approaches for handling "U" Type transmissions require further definition.

4.4.2 Merge Distribution

Figure 10 illustrates the number of merges derived from the merge process for the period 1-10 September 1984. These data are more of academic interest than they are of use to operational personnel. Rather, these data tend to characterize the beacon transmission environment. It is evident that 50% of the validated transmissions, i.e. at least one merge, are not heard again. In other words, the beacon activation period is short, of the order of 1-2 hours. These are probably the short duration false alarm incidents.

The number of merges seen at the CMCC is useful data for RCC controllers since it defines, to some extent, the age of the event and hence the likelihood that a true distress is involved.

4.5 Data Quantifiers

Thus far, it has been proposed that the evidence exists to allow immediate operational action on "E" and "I" Type transmissions. This categorization is based on cluster size alone. However, as discussed, this only constitutes about 27% of the data transferred from the LUT to the CMCC. The remaining 73%, or the "U" transmissions need the support of other information.

In the following discussion attention will focus on what information can be provided by the data quantifiers to help operational personnel define the type of action to be taken. Figure 11(a) and (b) summarizes the distributions of the Category Indicator, Q, and the CTA and TCA flags by transmission type for the 851 clusters.

The data in Figure 11(a) and (b) suggest the following points of interest. The Category Indicator and Q appear to be useful parameters to support actioning "U" Type transmissions. Generally speaking, these parameters identify good and poor quality data. This trend is not evident for the "E" and "I" Type transmissions. However, in this latter case, the data quantifiers are not as important since it has already been concluded that these are actionable incidents. The CTA and TCA flags, as would be expected, do not provide any guidance concerning the actionability of the

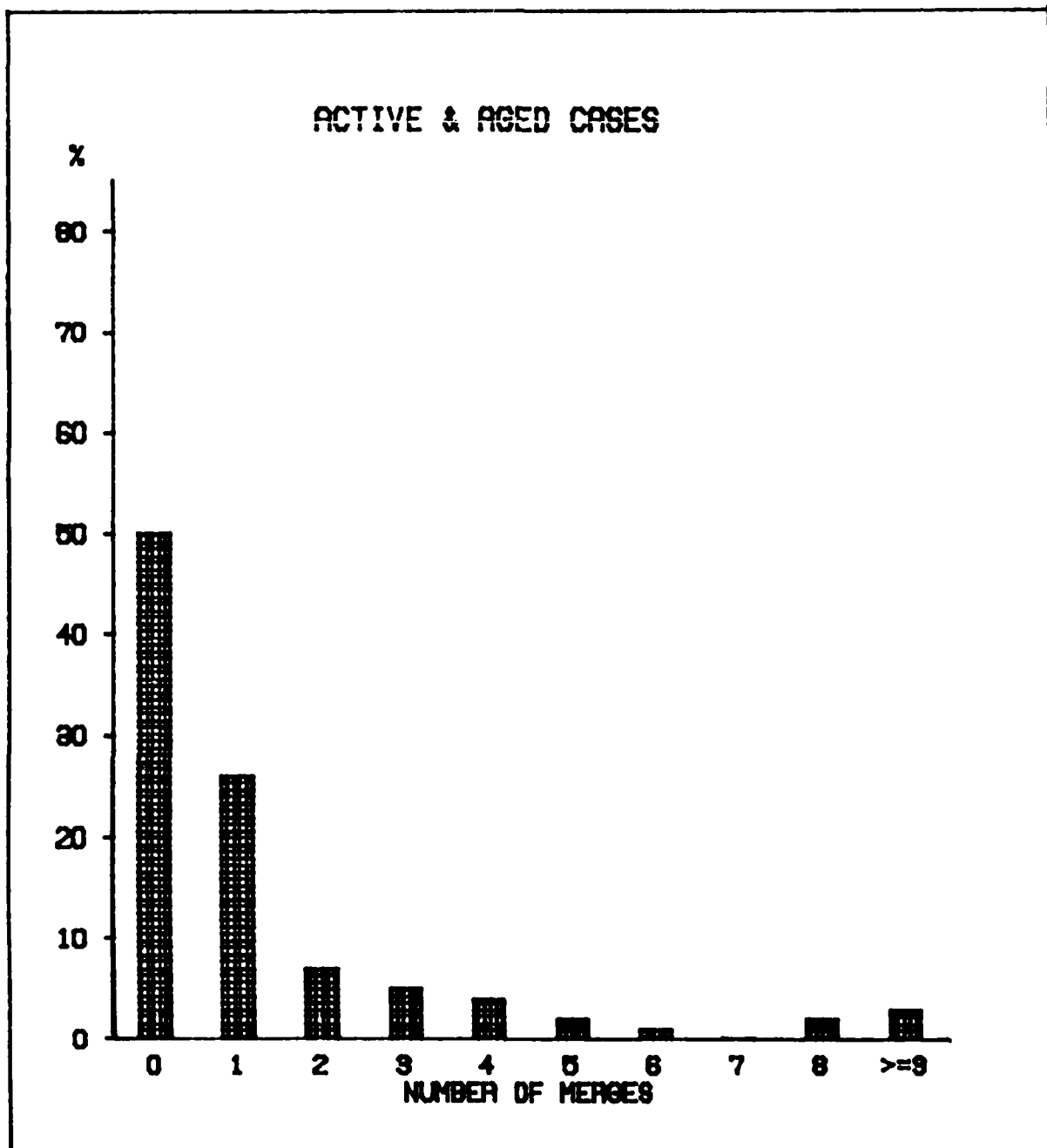
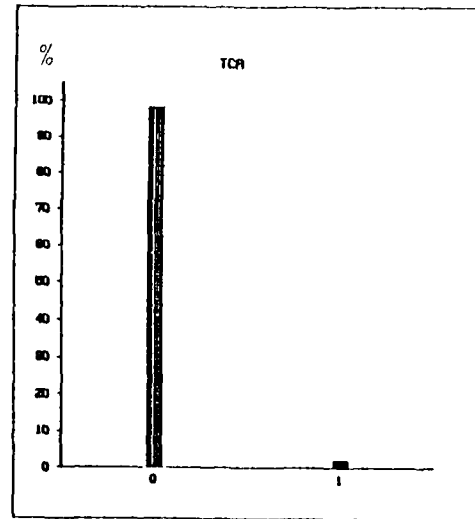
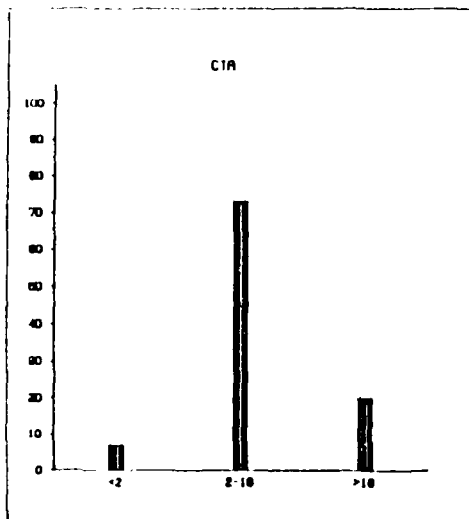
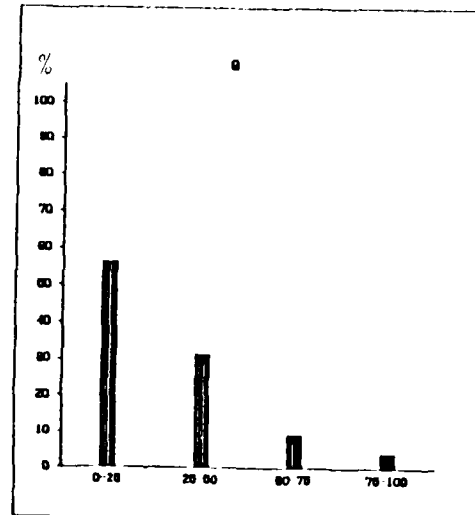
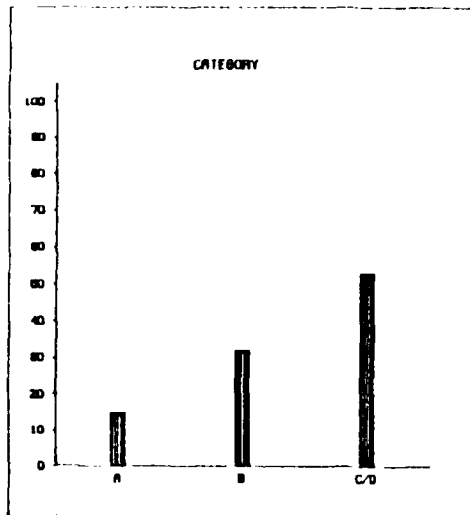
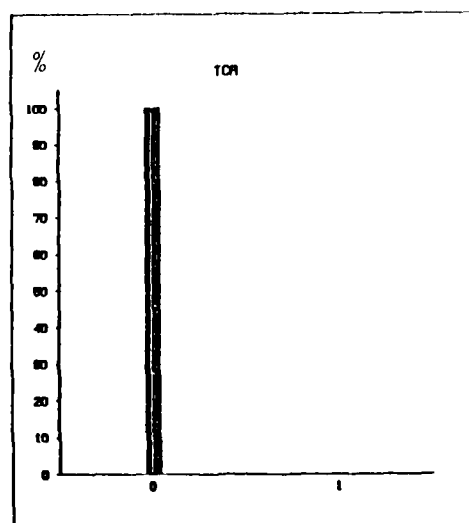
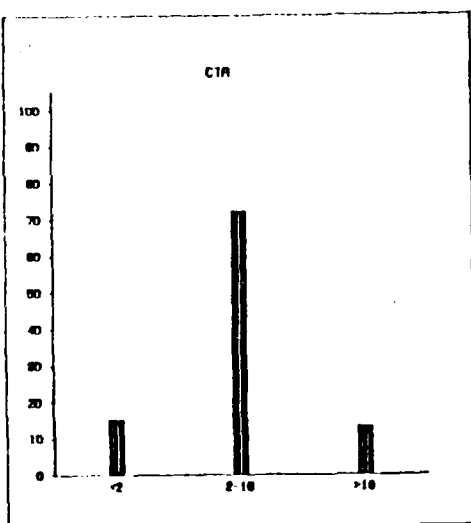
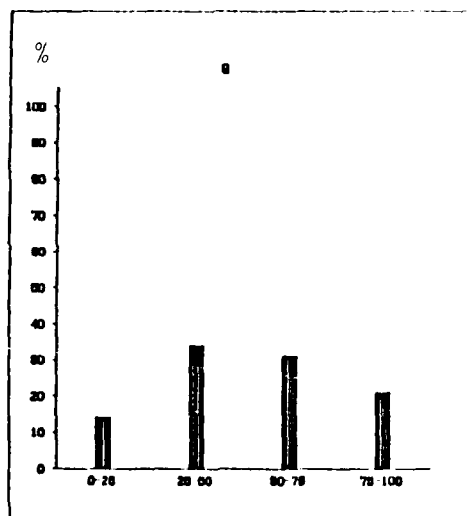
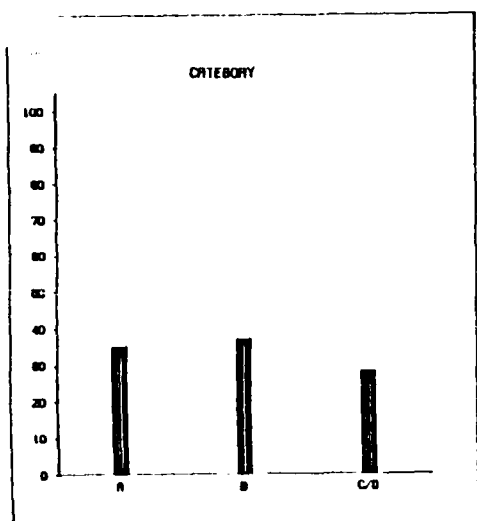


FIGURE 10: Merge Distribution



"U" Type Transmissions

FIGURE 11(a): Data Quantifier
Summary by Type



"E" and "I" Type Transmissions

FIGURE 11(b): Data Quantifier
Summary by Type

event. It should be clarified here that the point at issue is whether to action the detection or whether to wait for additional information. Once that decision has been made, then the data quantifiers have another very important function; they provide the user with an indication of how good the location estimate is.

A number of different definitions were identified to try and categorize incoming LUT data as being good, mediocre or bad. The proposed definition is as follows:

Good Data: Category A or B and $Q > 0.5$.
Bad Data: Category C or D and $Q \leq 0.5$.
Mediocre Data: Not good and Not Bad.

This definition was tested against the sample period data and the results are given in Table 4 and illustrated in Figure 12. It is evident from these data that the above definition works quite well. The suggestion has been made that all "E" and "I" Type transmissions are actionable incidents upon receipt from the LUT (the sample period suggests that 10% of these incidents were "orphan" incidents). This accounts for 228 detections or 27% of the incoming data. With reference to the "U" Type transmissions, it is now suggested that the data categorized as good or mediocre is amenable to immediate action. This categorization accounts for 308 detections or an additional 36% of the incoming data. The sample period suggests that 36 of these 308 incidents were "orphan" incidents, i.e. 6% of the "U" Type transmissions. The bad data for which no immediate action can be recommended consist of the 315 "U" Type transmissions with poor data quantifiers. These data constitute 37% of the incoming data. It is evident from Table 4 that 50% of these data can be actioned by subsequent pass validation, but in the first instance the quality of the information is not good enough to justify immediate actioning.

In summary, a method has been outlined which allows CMCC controllers with some degree of confidence to action 63% of all incoming SARSAT data. Furthermore, the approach is simple and would appear to work quite well when validated against historical data. The remaining 37% of the data does not require CMCC controller intervention until it is supported by subsequent pass or external information, e.g. SAR input. In volumetric terms and starting with the number of LUT detections, clearly 56% of the LUT data (371 detections suppressed at the LUT through the cluster process and 315 detections suppressed initially at the CMCC because of poor data quality) need not be actioned by CMCC controllers. The impact of the above strategy is to free up valuable CMCC controller time to action the better quality detections while at the same time minimizing the operational risk but maximizing resource utilization.

4.6 Case Studies

From the previous discussion it is clear that sufficient information is available from within the SARSAT system facilities to allow operational personnel to determine appropriate actioning of SARSAT data.

TABLE 4

Data Categorization Using
Data Quantifiers

	"U" Type Transmissions Cases	% of Total	"E" and "I" Type Transmissions Cases	% of Total	Totals Cases	% of Total
Good Data						
Orphan Incidents	6	0.8	7	3.1	12	1.4
Validated Incidents	<u>62</u>	<u>10.0</u>	<u>101</u>	<u>44.3</u>	<u>163</u>	<u>19.2</u>
	67	10.8	108	47.4	175	20.6
Mediocre Data						
Orphan Incidents	31	5.0	6	2.6	37	4.3
Validated Incidents	<u>210</u>	<u>33.7</u>	<u>61</u>	<u>26.8</u>	<u>271</u>	<u>31.8</u>
	241	38.7	67	29.4	308	36.1
Bad Data						
Orphan Incidents	114	18.3	11	4.8	125	14.7
Validated Incidents	<u>201</u>	<u>32.2</u>	<u>42</u>	<u>18.4</u>	<u>243</u>	<u>28.6</u>
	315	50.5	53	23.2	368	43.3
Totals						
Orphan Incidents	150	24.1	24	10.5	174	20.4
Validated Incidents	<u>473</u>	<u>75.9</u>	<u>204</u>	<u>89.5</u>	<u>677</u>	<u>79.6</u>
	623		228		851	

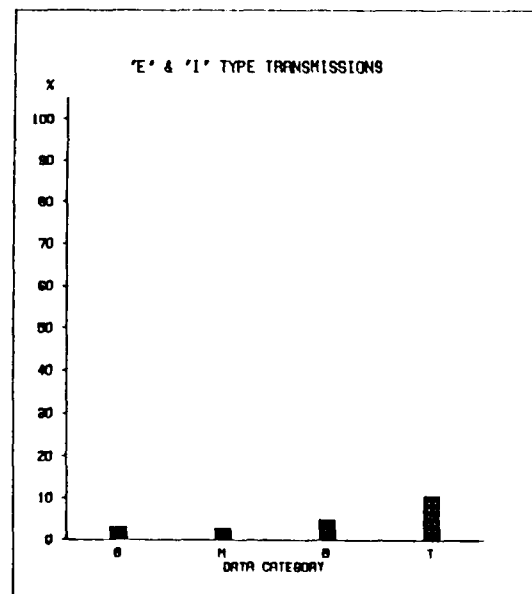
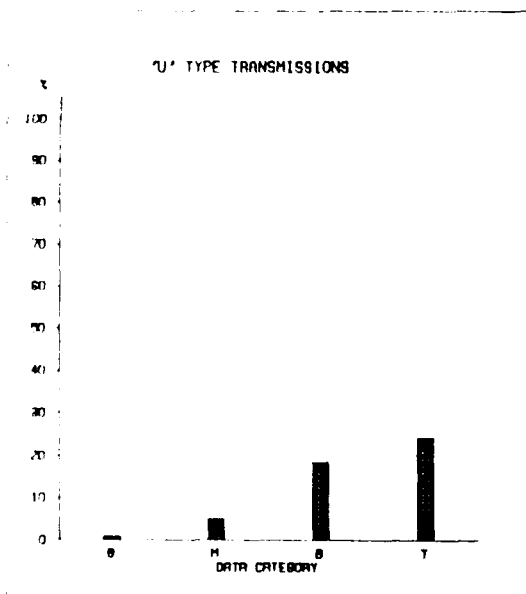
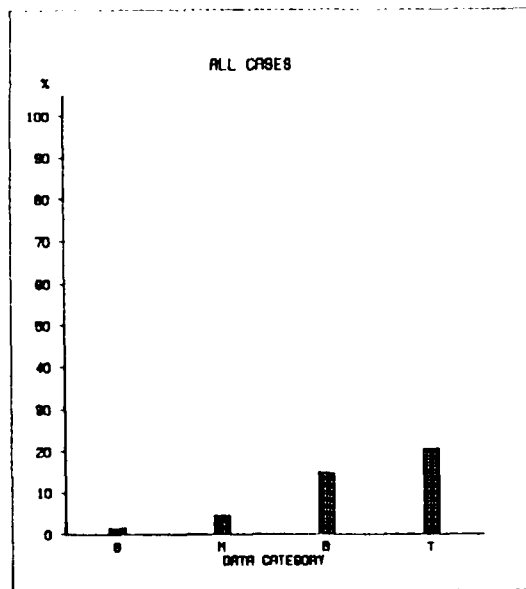


FIGURE 12: Data Categorization
"Orphan" Events

The topic not discussed thus far is the impact of the merge process, i.e. the Kalman Filter, on improving data quality. It is not within the scope of the current discussion to analyze the full impact of the merge process. Instead, a number of examples, chosen from the sample period 1-10 Sept 84, have been selected to illustrate the effect of the Kalman Filter.

Although the sample period, 1-10 Sept 84, was quite short it did contain three transmission events which illustrate the impact of the merge process. These included a search and rescue incident, a long duration (presumably false alarm) ELT transmission from the Chicago area and, presumably a test beacon transmission from the Goddard Space Flight Centre (GSFC) near Washington, D.C. Because each of the transmissions was different in nature, they illustrate different aspects of the merge process.

The SAR incident referred to above was SAR CF-WIJ which occurred on 7 September 1984. It involved a light plane, 2 people on board, which force landed on Lake Gachet, Province of Quebec, because it was low on fuel. Lake Gachet is about 70 nm NNW of Schefferville, Quebec, a relatively remote region. The pilot turned on his ELT to signal his situation. The incident site was estimated to be 56:05N, 67:15W.

SARSAT was used as an initial alert for SAR CF-WIJ and locations were derived from the following satellite passes: C2 07311, C2 07312, C2 07313 and C3 01071. In order to illustrate accuracy improvement due to the merge process, one needs the actual incident site and a number of detections from different satellite passes. These requirements were met with SAR CF-WIJ.

Figure 13 illustrates the effect of the Kalman Filter (the CMCC data) in estimating the location of the incident. For comparison, the LUT location estimates are included in Figure 13. It is significant to note that by the third detection, the error in estimation is under 10 km and stabilizing quite well. By comparison, the LUT estimates can be of the order of 30 km different to the CMCC estimates provided by the Kalman Filter.

The GSFC test beacon and the Chicago area transmission provided additional visibility into the impact of filtering LUT data because of the duration of the transmissions. The GSFC data spanned the period 1 September to 3 September, and data from 16 passes were merged. The Chicago area transmission was initially detected on 4 September and last seen on 7 September. In the latter case, data from 17 passes were used. The large number of repeat detections afforded a good opportunity to illustrate the difference between the source LUT data and the Kalman filtered CMCC data. The two characteristics chosen for illustration were the impact on location estimation and the trend in parameter estimation.

The actual location of the beacon was not known for either the GSFC or the Chicago area transmitters. Therefore, the last available Kalman Filter estimate was used as the best approximation to the true location of the transmission.

Based on the above approach, error diagrams were developed for

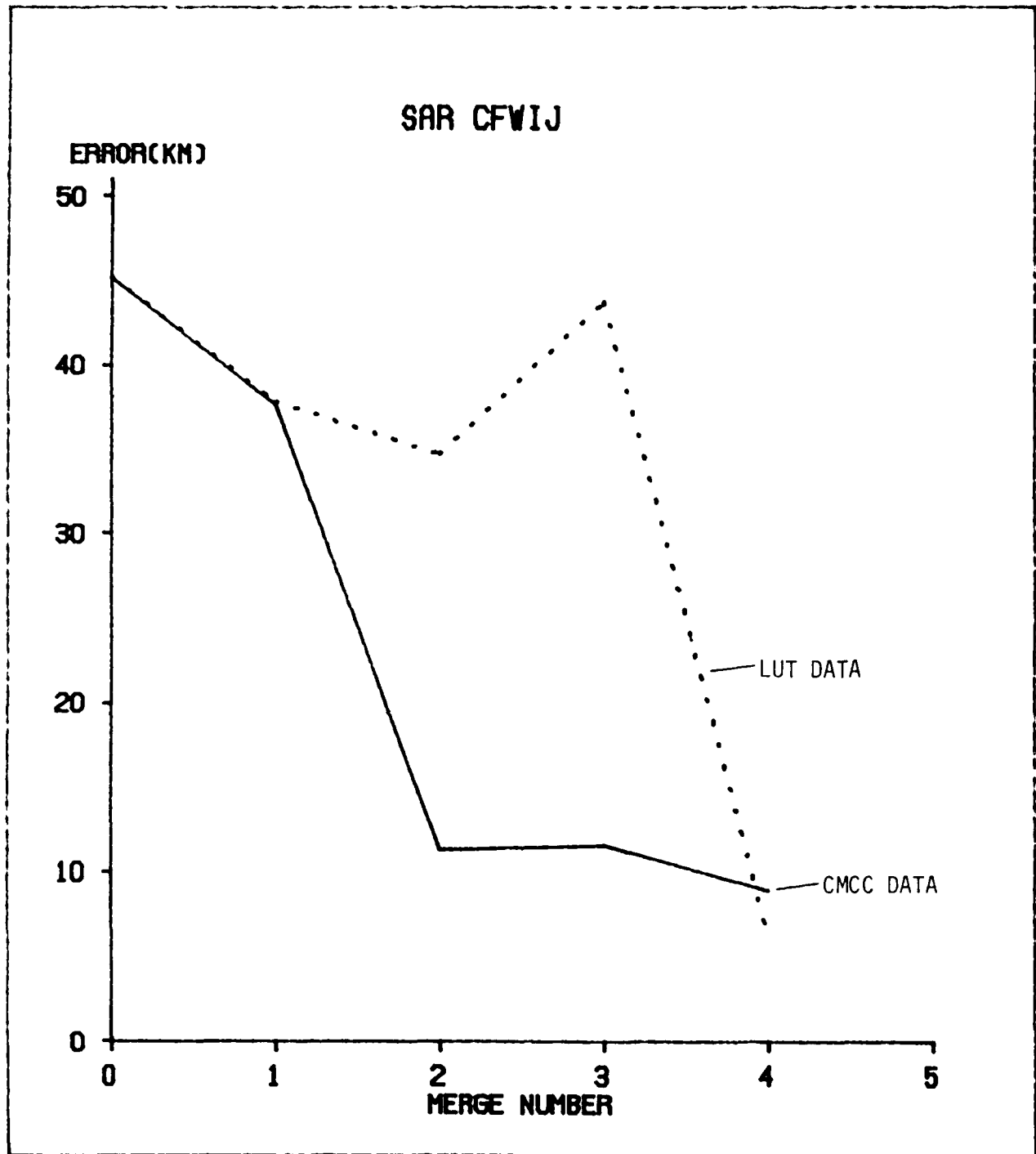


FIGURE 13: Error (km) in Location Estimation
LUT Versus CMCC Data

the LUT data and the CMCC data for each of the transmission sites. These are illustrated in Figure 14. The impact on location estimation is obvious, and requires no discussion.

In order to update location estimates, the Kalman Filter requires estimates of the standard deviation in latitude and longitude. These are the parameters VLAT and VLONG discussed in Section 3.2.5. With each successive detection, these parameters are updated. Necessarily, with more information, i.e. additional pass detections, the error should become smaller. Similarly, the estimation of the BIAS should improve with successive passes and hence the updated VBIAS should reduce with time.

In Figure 15, the trend in the estimation of VLAT, VLONG and VBIAS are illustrated for the two transmission sites, i.e. the GSFC beacon and the Chicago area transmission. These data are plotted as a percent of the initial estimate. It is obvious that the Kalman Filter is working quite well. However, it is more interesting to note that the biggest gains in terms of reducing error occur in the first three to four detections. This is significant since, referring to Figure 10, the number of occasions when multiple detections occur outside this range are small.

As an interesting aside to the above discussion, the linear deviation in the estimate of BIAS for the two transmissions is also plotted in Figure 15. Once again, because the true transmission frequency was not known, the initial estimate of BIAS was used as the reference point. It is obvious from these data why the assumption was made that the GSFC transmitter was a test beacon. The deviation in the BIAS estimate was negligible. The Chicago transmission is significantly different. While in absolute terms the variation is probably not significant, i.e. 1 KHz in 121.5 MHz, the Kalman Filter data does point at the positive drift in the beacon. The other interesting conclusion drawn from these data is that the LUT estimation of BIAS is good since in effect the sample period provided a comparison of a test beacon (presumably with good transmission characteristics) being demonstrated to have these good characteristics, and a real beacon being demonstrated to have less than ideal transmission characteristics.

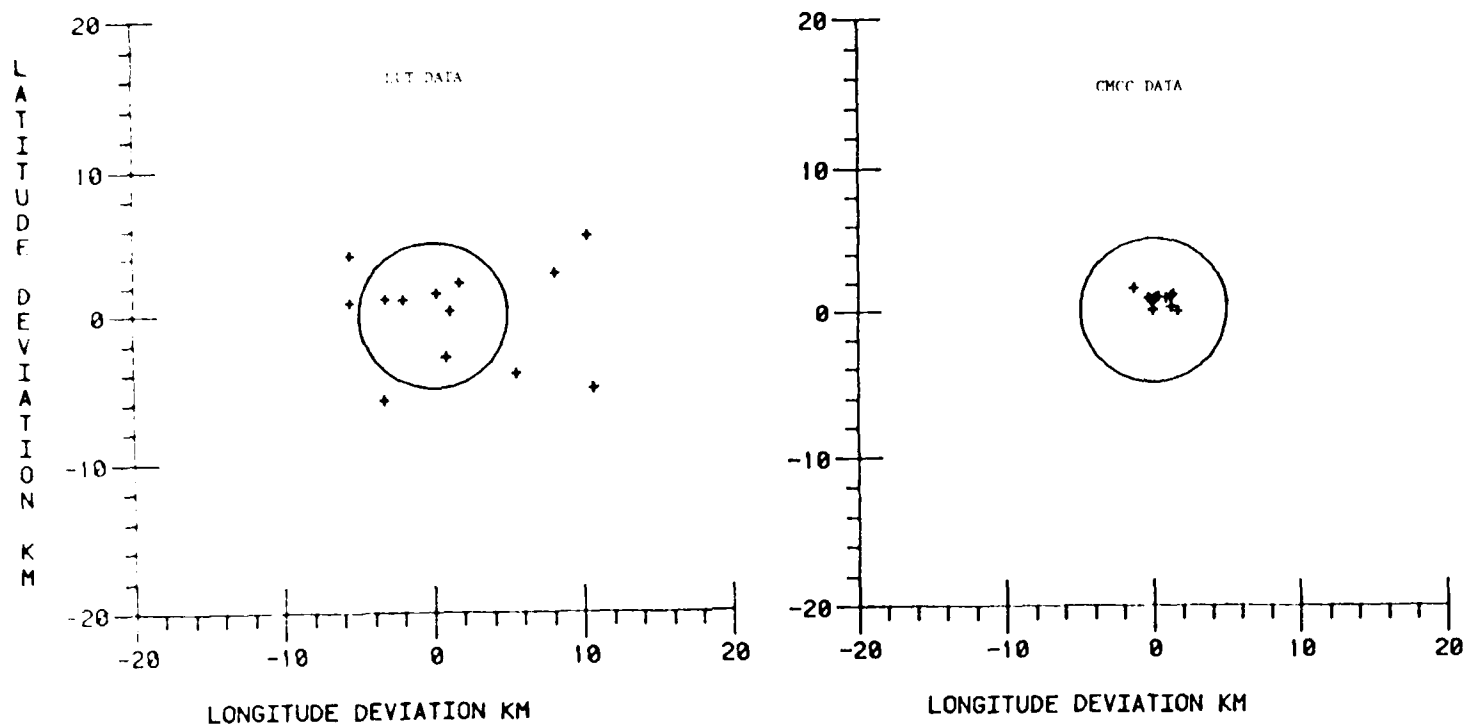
Therefore, in this brief discussion, the impact of merging repeat detection data through Kalman Filter techniques has been illustrated. It is readily apparent that the net improvement is significant and most of the gains are made by the third to fourth detection.

5.0 SUMMARY COMMENTS/RECOMMENDATIONS

The problems associated with the flow and handling of SARSAT 121.5/243 MHz alert data have been discussed. The nature of the problem has been characterized and methods to support operational actioning of these data have been postulated, studied and validated.

The objectives of this developmental study have been achieved. A LUT to CMCC parameter definition is given and a suggested data flow

GSFC TEST BEACON



CHICAGO AREA TRANSMISSION

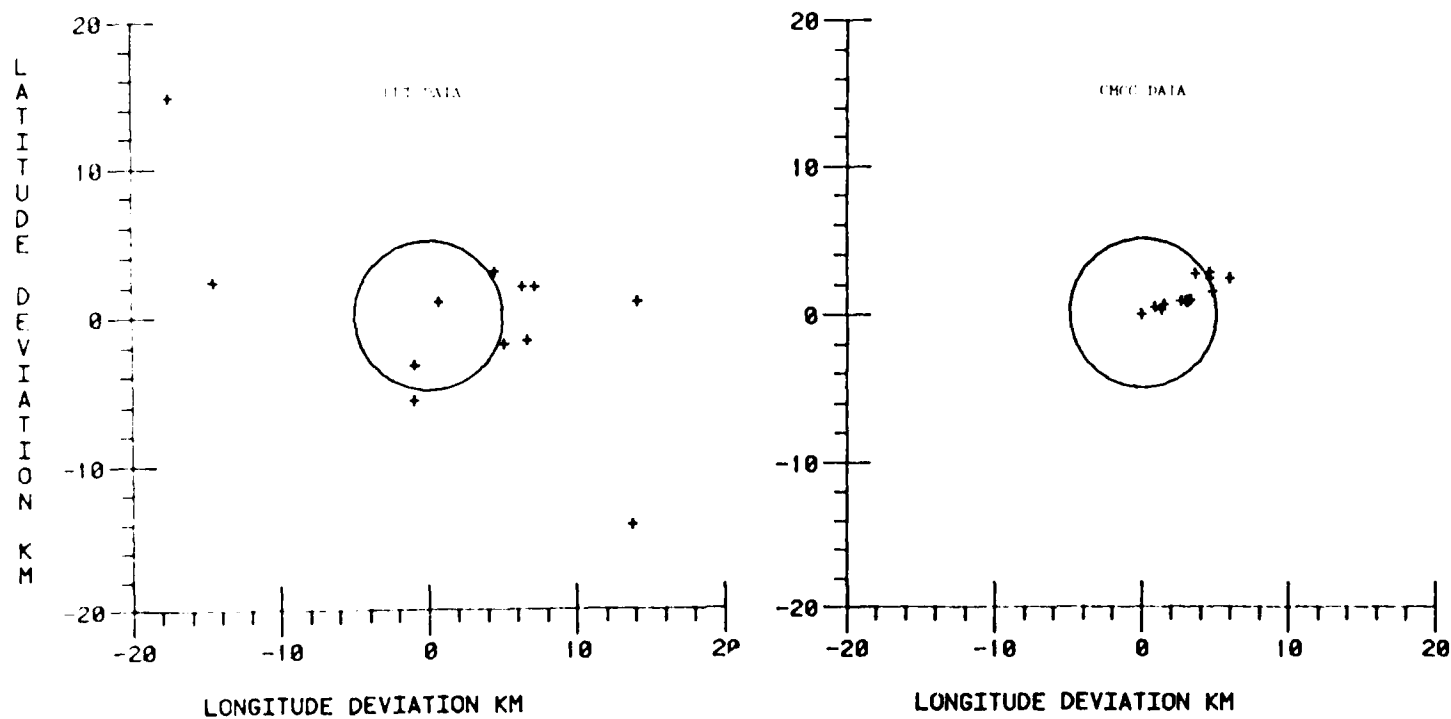


FIGURE 14: Location Error
LUT Versus CMCC Data

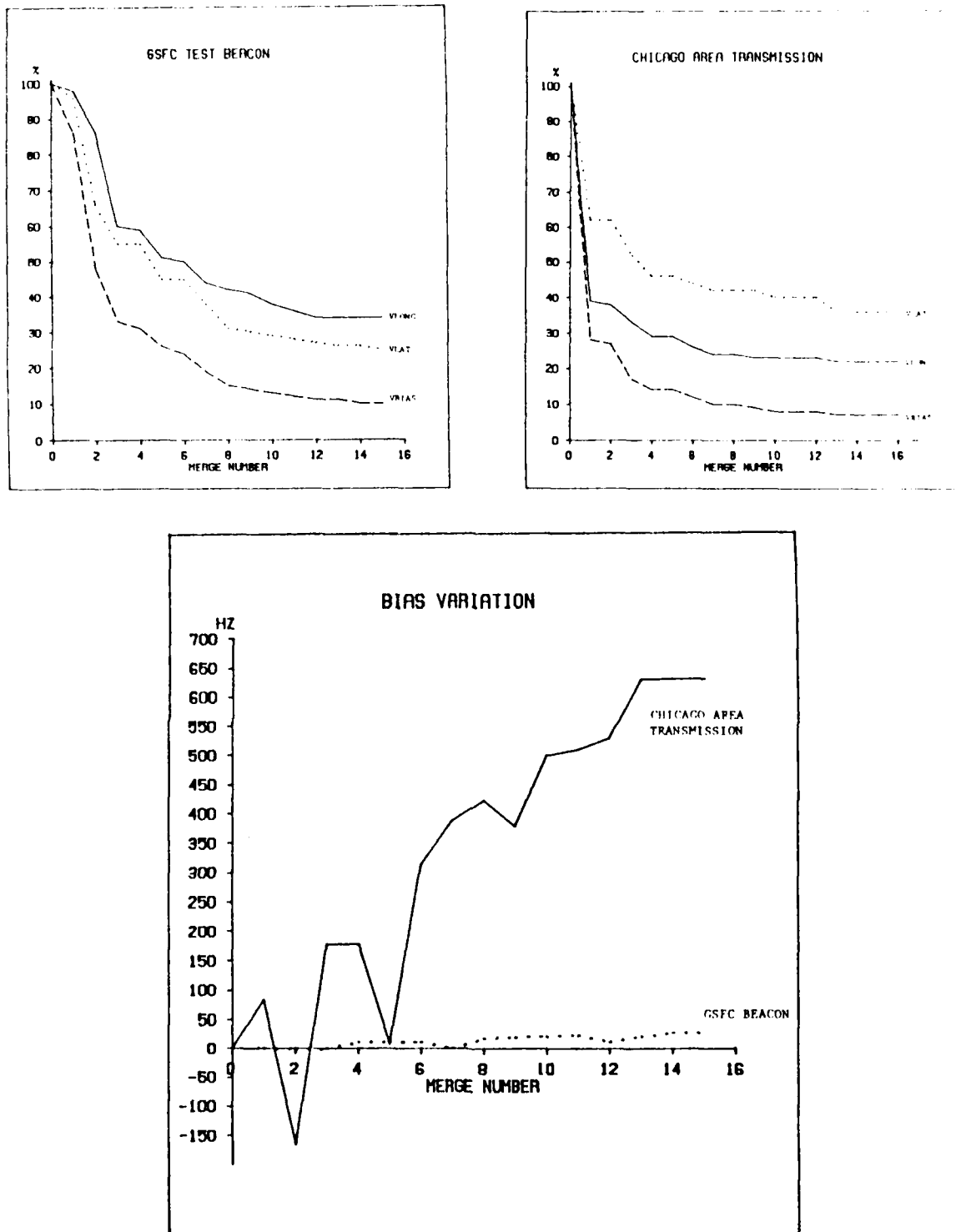


FIGURE 15: Impact of the Merge Process on Parameter Estimation

methodology has been developed. The impact and utility of the approach discussed has been validated and characterized using historical SARSAT data.

It is recommended that the designers and developers of future improved SARSAT facilities take into account the results of the work discussed herein. Specifically, it is recommended that a cluster algorithm be built into future LUT designs in order that the requirements of parameter transfer definition be met. The impact of having a merge algorithm at the CMCC is well understood and has been demonstrated to significantly improve data quality. Finally, steps must be taken to reduce the volume of data currently being presented to CMCC controllers for processing and to the SAR community for its action.

At the operational level, if the methodology recommended was implemented, two significant outcomes are anticipated. Firstly, CMCC controllers, with little risk in the loss of SAR efficiency, can be relieved from having to action 50% of the LUT generated data. Furthermore, there would be a significant reduction in the amount of poor quality data distributed to RCCs for their action. Rules are then suggested for actioning the remaining data. In their simplest terms these rules are as follows: action all data for which cluster sizes are greater than one (the level of action is tempered by the quality of the data as reflected in the data qualifiers); action only those single element clusters when the data qualifiers (Category and Q) indicate that the data is good or at least mediocre. The above recommended procedure is viewed as being relatively conservative.

As a final footnote to the discussion, the studies discussed and documented herein have illustrated that technically, the Canadian SARSAT facilities function extremely well. However, in terms of handling the data, in an analogy to a management information system, they have serious shortcomings which impact in a significant manner on operational efficiency. Recommendations are made, and approaches suggested to resolve these shortcomings.

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13. ABSTRACT The transfer of beacon alert data from the SARSAT Local User Terminal (LUT) to the Canadian Mission Control Centre (CMCC) has shortcomings. A critical review of the transfer of information between these two SARSAT facilities was undertaken. As a result of this review, a recommended LUT to CMCC data flow methodology has been developed, characterized and evaluated. Implementation of the recommendations outlined should improve the operational usefulness of the SARSAT system.		

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